TOPIC 14 – HL BONDING
14.2 – HYBRIDIZATION

IB Chemistry

T04D07

Mr. Martin Brakke

Hybridization

- 14.2.1 Describe pi and sigma bonds. (2)
- 14.2.2 Explain hybridization in terms of the mixing of atomic orbitals to form new orbitals for bonding. (3)
- 14.2.3 Identify and explain the relationships between Lewis structures, molecular shapes and types of hybridization (sp, sp^2 and sp^3). (3)

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Pi and Sigma

14.2.1 Describe pi and sigma bonds. (2)

- Going beyond SL material, a more precise model of bonding can help to describe bonding detail where the “dot and cross” method cannot.
- As we look at the interactions between atomic orbitals, we find that orbitals overlap in two possible directions, mixing their energies
- This theory is known as the **molecular orbital theory (MO Theory)**
  - The strength is related to the match in energy levels and the degree of overlap

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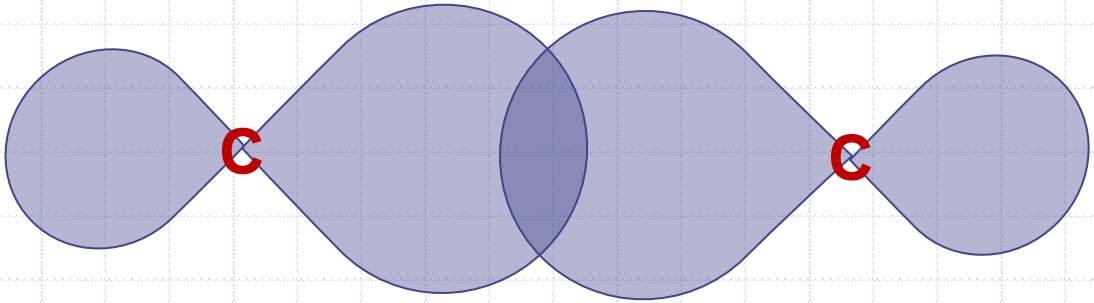
Sigma Bonding

- A **sigma (σ)** bond is a single bond in which orbitals overlap head-to-head directly between atomic nuclei
- P orbitals overlap sideways
- Sigma bonds are relatively unreactive but are important in determining the shape of a molecule or ion



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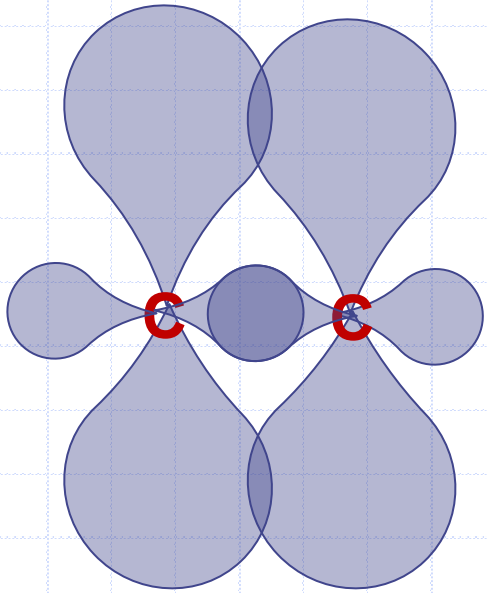
Pi Bonding

- A **pi (π)** bond occurs when two parallel p orbitals undergo sideways overlap.
- Occurs in double bonds (1σ , 1π)
- Occurs in triple bonds (1σ , 2π)
- Since there is sideways overlap, the nuclei are not shielded (as in σ bonds) and electrons are further away from the nucleus and therefore more polarizable and chemically reactive
- When a double bond occurs, the sigma bond is stronger than the weak pi bond



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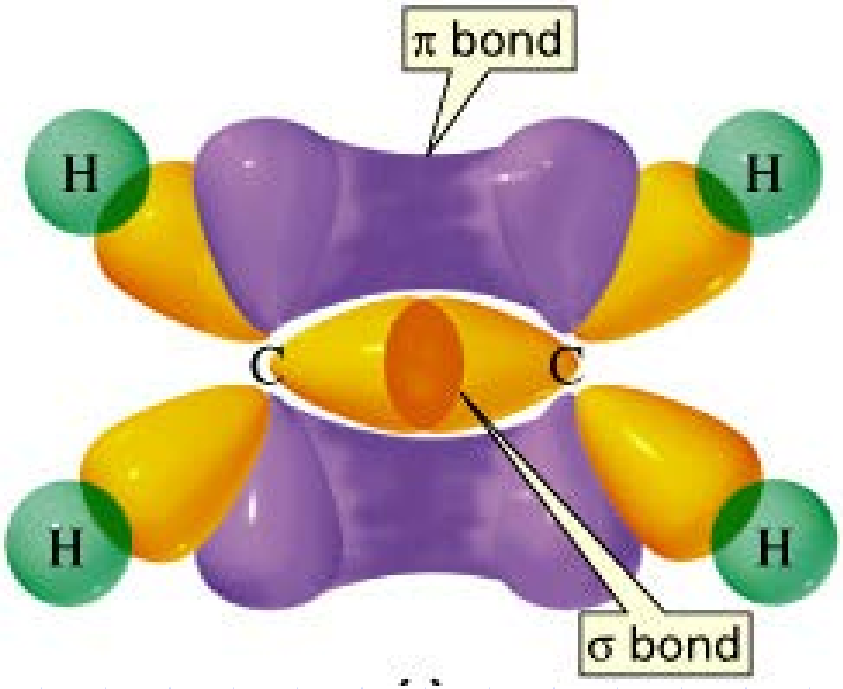
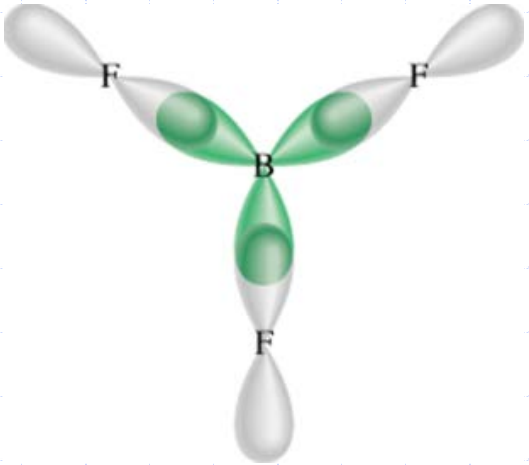
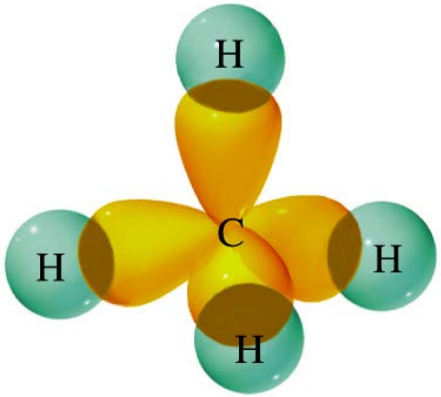
View of Sigma vs Pi







Mixing of Orbitals

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14.2.2 Explain hybridization in terms of the mixing of atomic orbitals to form new orbitals for bonding. (3)

- Orbitals of the *same atom* can overlap, merge and undergo a process of **hybridization** to form a new set of **hybrid atomic orbitals**
  - The orbitals formed have a specific shape and orientation
  - The number of hybrid orbitals formed is equal to the number of atomic orbitals involved in the hybridization process
  - These are sp, sp^2, sp^3, sp^3d, sp^3d^2
  - Hybridization is a mathematical model used to describe localized bonds and cannot be directly studied or measured

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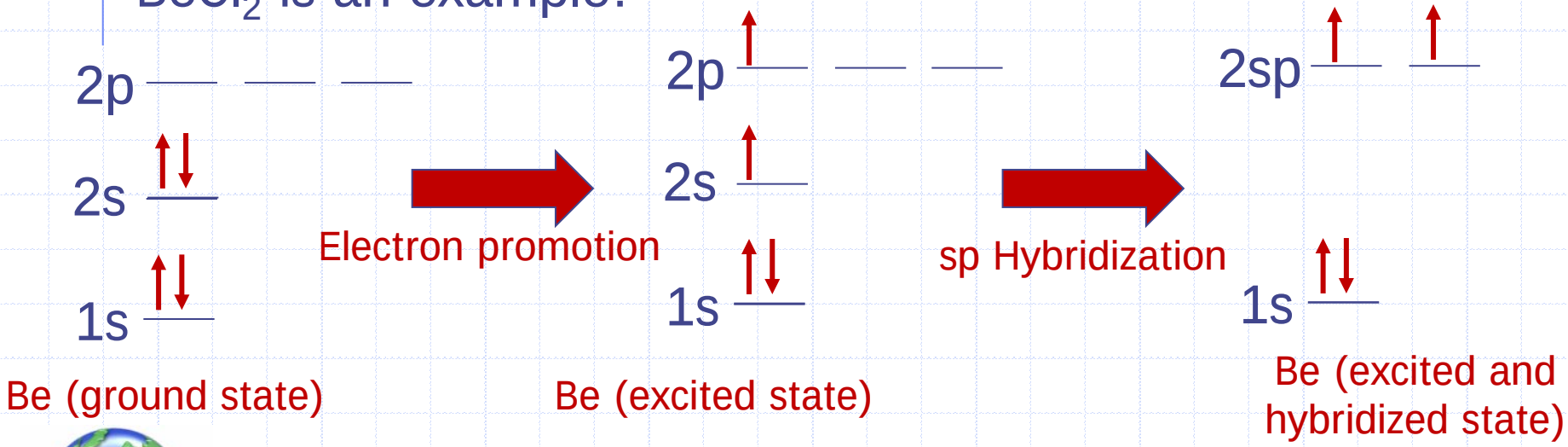
sp Hybridization - Linear

- A single s and single p orbital will overlap to form two identical sp hybridized orbitals 180º from each other

- $BeCl_2$ is an example:



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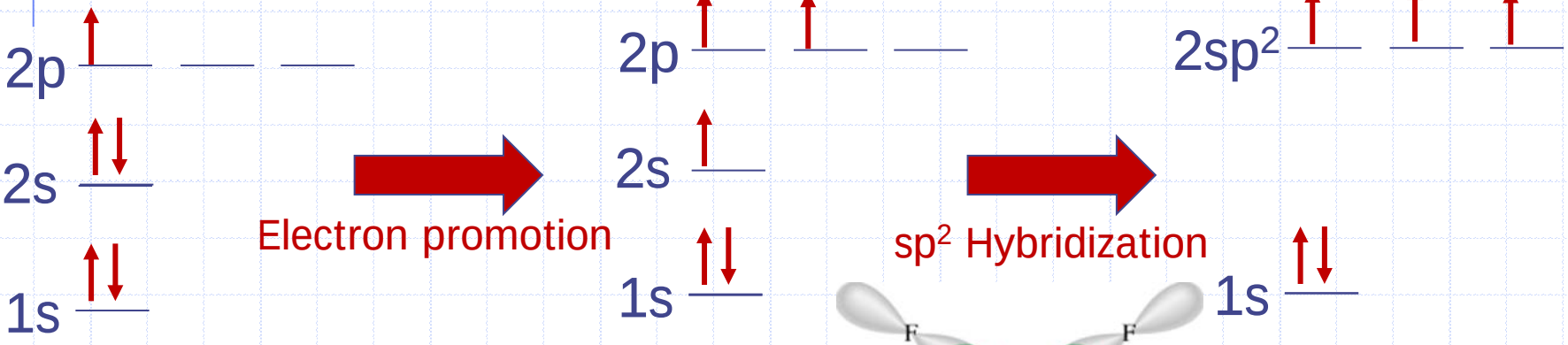
sp^2 Hybridization – Trig Planar

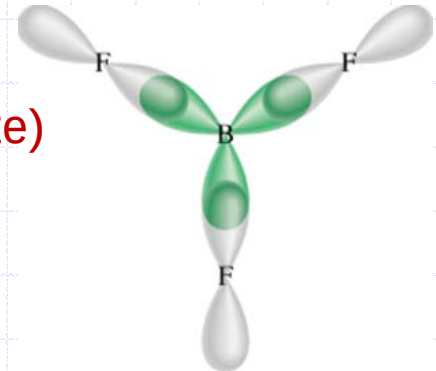
- sp^2 hybridization involves the combination of one s and two p orbitals. All three result in the same shapes, orientations, and energies

- BF_3 as an example



B (ground state)

B (excited state)



B (excited and hybridized state)

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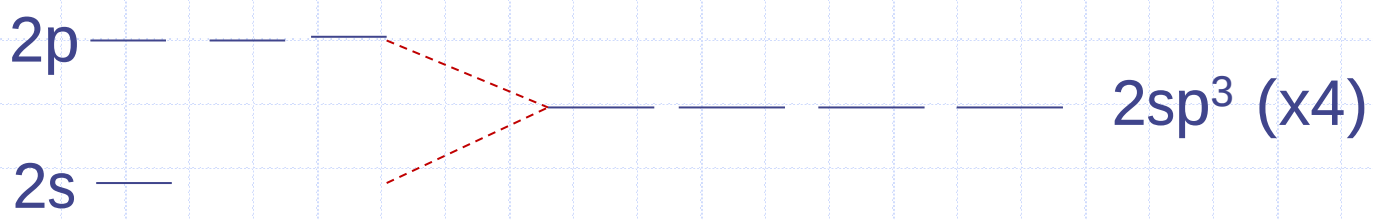
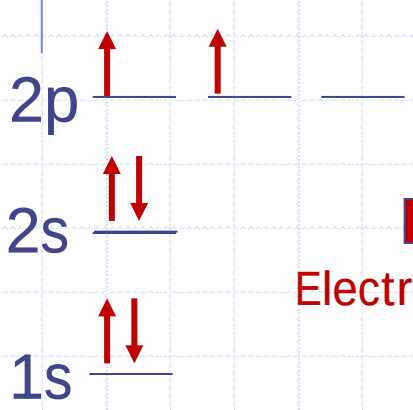
sp^3 Hybridization - Tetrahedral

- Hybridization of one s orbital and three p orbitals

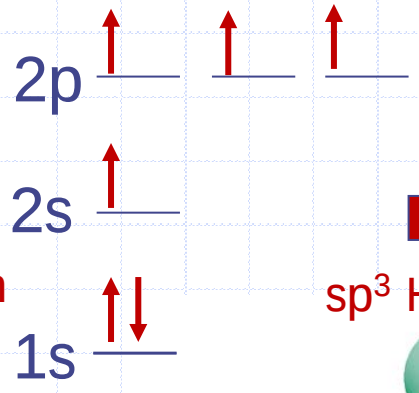


- CH_4 as an example:



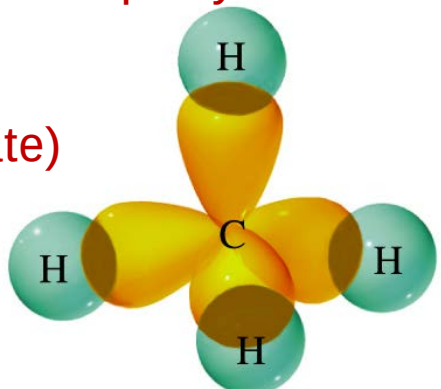
C (ground state)

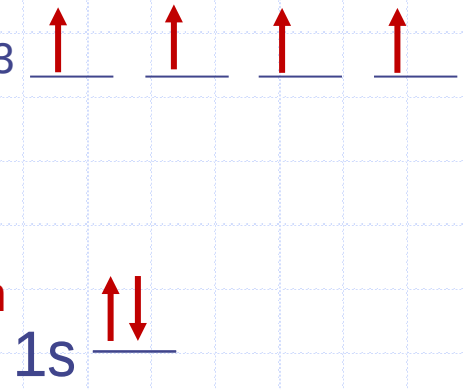
Electron promotion



C (excited state)

sp^3 Hybridization





C (excited and hybridized state)

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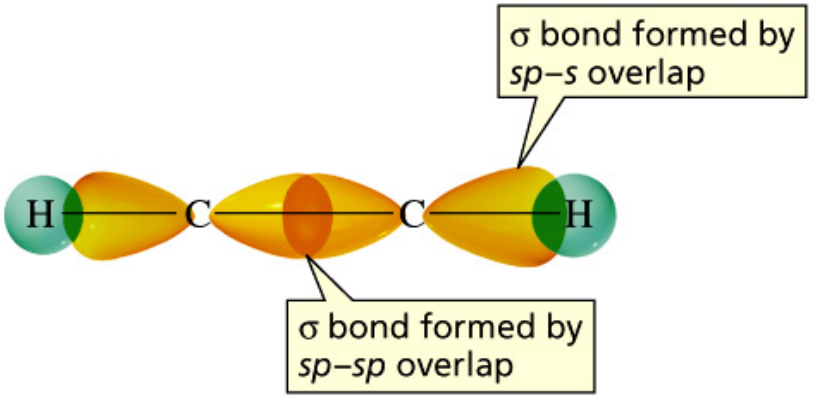
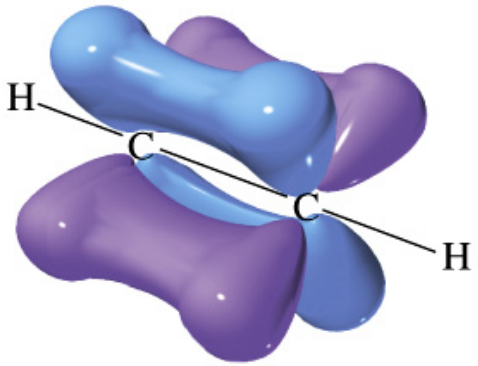
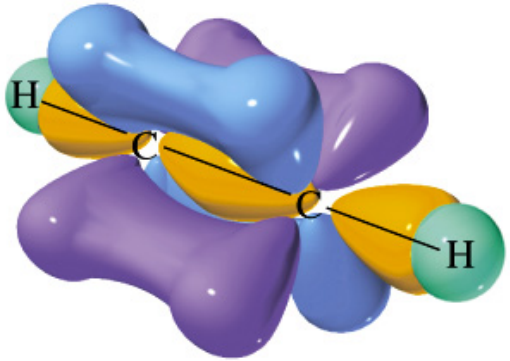
Hybridization in C_2H_2



(a)



(b)



(c)

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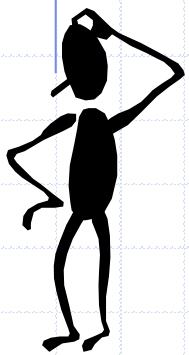
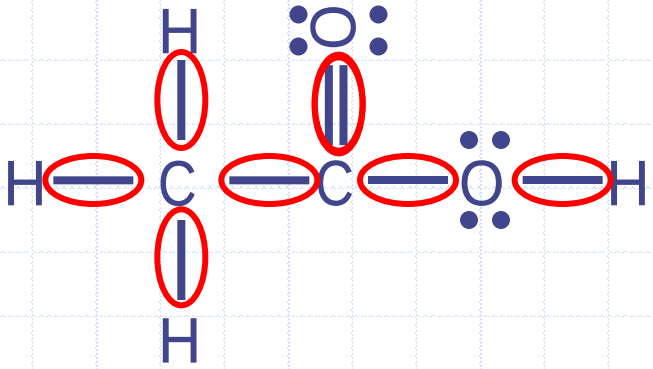
Sigma (σ) and Pi Bonds (π)

- Single bond — 1 sigma bond
- Double bond — 1 sigma bond and 1 pi bond
- Triple bond — 1 sigma bond and 2 pi bonds



How many σ and π bonds are in the acetic acid (vinegar) molecule CH_3COOH?



σ bonds = 6 + 1 = 7

π bonds = 1

Shapes and Hybridization

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14.2.3 Identify and explain the relationships between Lewis structures, molecular shapes and types of hybridization (sp, sp^2 and sp^3). (3)

Hybridization of Central atom	# Negative Charge Centers	# Covalent bonds	# Lone Pairs	Shape	Examples
sp	2	2	0	Linear	BeF_2, CO_2
sp^2	3	3	0	Trig Planar	BF_3, Graphite, C-60
sp^2	3	2	1	V-shaped/ Bent	SO_2, NO_2^-
sp^3	4	4	0	Tetrahedral	CH_4, diamond, SO_4^{2-}
sp^3	4	3	1	Pyramidal	NH_3, H_3O^+
sp^3	4	2	2	Bent	H_2O, H_2S
sp^3d	5	5	0	Trig Bi-pyramidal	
sp^3d^2	6	6	0	Octahedral	